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Phytase in Swine Diets

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Summary and Implications

An experiment was conducted to determine whether phytase additions to swine growing-finishing diets improved the availability of lysine, calcium, energy and phosphorus in corn and soybean meal-based diets. Diets investigated for growing-finishing barrows of high-lean-gain potential included: 1) University of Nebraska recommended diet formulations; 2) diets formulated to contain 85% of the lysine recommended; 3) lysine-deficient diets formulated with phytase; 4) phytase-formulated diets with phytase deleted; and 5) phytase-formulated diets with phytase deleted and with additional calcium and phosphorus. Pigs fed diets formulated to 85% of the recommended lysine level had slower growth, slower daily lean gain, poorer feed conversion, and less carcass lean. There was no effect of phytase addition or deletion on growth, feed efficiency, or carcass lean. There was no effect of phytase addition or deletion on bone strength or bone ash. These results do not agree with the large body of evidence regarding the improvement in availability of phosphorus in corn and soybean meal with the addition of phytase to swine diets and may be related to the growth impairment associated with the lysine deficiency.

Introduction

Phosphorus is a key mineral required by pigs for growth of body tissues. Feeding diets deficient in phosphorus results in reduced growth, reduced lean tissue accretion and reduced bone development.

In corn and soybeans, the major feed grain and protein supplement in swine diets in Nebraska, the majority of the phosphorus occurs as an organic complex called phytate. Because pigs secrete very limited amounts of the enzyme phytase, they are unable to use most of the phosphorus in these feed grains. For example, while corn and 44% protein soybean meal contain .28% and .60% total phosphorus on an as-fed basis, only .04% and .20%, respectively, are available. Thus, swine diets are typically formulated using inorganic phosphorus sources such as dicalcium phosphate to meet the pigs' requirements. In addition to being relatively unavailable, there is evidence that phytate binds some of the calcium and other minerals in swine diets and reduces their availability.

It is now possible to add the enzyme phytase to swine diets. The result is an increase in the availability of phytate-phosphorus and a resulting decrease in the amount of inorganic phosphorus addition necessary to meet the needs of the pig and a decrease in the amount of undigestible phosphorus excreted in the manure. Experimental evidence from poultry and swine suggests that in addition to increasing phytate phosphorus availability, phytase additions to the diet also increase the calcium, lysine and energy digestibility of feed grains. The purpose of the following experiment was to evaluate the possibility that the use of a commercial phytase source in corn-soybean meal diets would result in increased calcium, lysine and energy availability, in addition to improved phosphorus utilization.

Methods

The experiment was conducted at the University of Nebraska's Haskell Ag Lab at Concord. Pigs were housed in partially slatted pens measuring 6 ft x 15 ft with 13 pigs per pen (6.9 ft^2/pig). In Trial 1, which began in March, the facilities were mechanically ventilated. Pigs in Trial 2 (began in May) and Trial 3 (began in November) were housed in naturally ventilated facilities. Sprinklers were used for summer heat relief with sprinkling set to begin at 80^{o}F.

In each of three trials, 260 crossbred PIC barrows were allocated at arrival based on weight outcome groups (light and heavy) to experimental dietary treatments (Tables 1 and 2). The experimental treatments were:

A) University of Nebraska recommended diets with added fat (**UNL**).
B) Lysine at 85% of UNL. All other nutrients at same level of addition (**85**).
C) Lysine at 84% of UNL with phytase added based on credits for lysine, energy, Ca and P per phytase recommended equivalencies (**PHY**).
D) PHY without phytase (**NEG**).
E) NEG with P and Ca added to same level as UNL and 85 (**MIN**).

The UNL diets were formulated to contain 1.00%, 0.88%, 0.73% and 0.60% lysine with diets switched on the week individual pens of pigs weighed 80, 130 and 190 pounds. Using corn and soybean meal, UNL diets were formulated for lysine, calcium, total phosphorus and available phosphorus according to the 1995 edition of the *Nebraska and South Dakota Swine Nutrition Guide* (EC95-273). Fat was added to treatments UNL and 85 to increase the metabolizable energy content by the amount credited to phytase in treatment PHY. Phytase diets were formulated using the nutrient availability matrix of the phytase supplier. When added at 500 FTU (phytase units)/kg, the matrix estimated that phytase

Table 1. Experimental diet composition, 40 to 130 pound pigs.

	40 to 80 lb					80 to 130 lb				
	Treatment[a]					Treatment				
Item	UNL	85	PHY	NEG	MIN	UNL	85	PHY	NEG	MIN
Ingredient, lb/ton										
Corn	1352	1468	1503.3	1505	1494	1448	1551	1581.3	1583	1572
Soybean meal, 44% CP	580	465	455	455	455	486	385	380	380	380
Fat	19	16				19	16			
Dicalcium phosphate, 18.5% P	26	28	15	15	28	23	24	11	11	24
Limestone	13	13	15	15	13	14	14	16	16	14
Salt	6	6	6	6	6	6	6	6	6	6
Vit/TM mix[b]	4	4	4	4	4	4	4	4	4	4
Phytase[c]			1.7					1.7		
Composition										
ME, kcal/lb	1508[d]	1509	1497	1500	1491	1514	1514	1502	1505	1497
Lysine, %	1.00(.97[e])	.85(.88)	.84(.83)	.84(.83)	.84(.80)	.88(.87)	.75(.76)	.74(.74)	.74(.73)	.74(.75)
Calcium, %	.69(.80)	.70(.70)	.58(.63)	.58(.61)	.70(.64)	.66(.74)	.66(.71)	.54(.58)	.54(.52)	.66(.65)
Phosphorus, %	.60(.58)	.60(.55)	.48(.44)	.48(.47)	.59(.58)	.55(.57)	.54(.55)	.43(.44)	.43(.40)	.54(.52)
Total available phosphorus, %	.34	.34	.34	.22	.34	.30	.30	.30	.18	.30
Particle size, microns[e]						818	846	851	852	842
Phytase activity, FTU/kg[c]			467					445		

[a]UNL = University of Nebraska recommended; 85 = Lysine at 85% of UNL; PHY = Phytase to 85 diet with credits for lysine, energy, calcium, and phosphorus; NEG = PHY diet with phytase deleted; MIN = NEG diet with calcium and phosphorus added.
[b]Provided the following per pound of complete diet: Zn, 90 ppm; Fe, 80 ppm; Mn, 32 ppm; Cu, 10 ppm; I, 0.4 ppm; Se, 0.3 ppm; Vitamin A, 2500 IU; Vitamin D 500 IU; Vitamin E, 11 IU; Vitamin K, 1 mg; Choline, 30 mg; Niacin, 12 mg; D-pantothenic acid, 8 mg; Riboflavin, 2 mg; Vitamin B_{12}, .024 mg.
[c]Natuphos 600, BASF, Inc., Mt. Olive, NJ 07828.
[d]Calculated composition.
[e]Analyzed composition, Ward Labs, Kearney, NE 68848.

Table 2. Experimental diet composition, 130 pounds to slaughter.

	130 to 190 pounds					190 pounds to slaughter				
	Treatment[a]					Treatment				
Item	UNL	85	PHY	NEG	MIN	UNL	85	PHY	NEG	MIN
Ingredient, lb/ton										
Corn	1569	1651	1690.3	1692	1681	1672	1743	1778.3	1780	1769
Soybean meal, 44% CP	370	290	275	275	275	270	200	190	190	190
Fat	18	15				18	16			
Dicalcium phosphate, 18.5% P	19	20	7	7	20	16	16	3	3	16
Limestone	14	14	16	16	14	14	15	17	17	15
Salt	6	6	6	6	6	6	6	6	6	6
Vit/TM mix[b]	4	4	4	4	4	4	4	4	4	4
Phytase[c]			1.7					1.7		
Composition										
ME, kcal/lb	1521[d]	1521	1510	1513	1505	1528	1528	1516	1519	1511
Lysine, %	.73(.71[e])	.62(.62)	.61(.61)	.61(.60)	.61(.62)	.60(.58)	.51(.51)	.50(.50)	.50(.51)	.50(.50)
Calcium, %	.60(.89)	.60(.82)	.48(.44)	.48(.47)	.59(.62)	.55(.55)	.56(.64)	.44(.42)	.44(.53)	.55(.65)
Phosphorus, %	.49(.50)	.49(.52)	.37(.36)	.37(.36)	.49(.48)	.45(.42)	.44(.47)	.32(.31)	.32(.33)	.44(.42)
Available phosphorus, %	.25	.25	.25	.13	.25	.21	.21	.21	.09	.21
Particle size, microns[e]	792	828	812	832	823	882	851	827	843	859
Phytase activity, FTU/kg[c]			495					533		

[a]UNL = University of Nebraska recommended; 85 = Lysine at 85% of UNL; PHY = Phytase to 85 diet with credits for lysine, energy, calcium, and phosphorus; NEG = PHY diet with phytase deleted; MIN = NEG diet with calcium and phosphorus added.
[b]Provided the following per pound of complete diet: Zn, 90 ppm; Fe, 80 ppm; Mn, 32 ppm; Cu, 10 ppm; I, 0.4 ppm; Se, 0.3 ppm; Vitamin A, 2500 IU; Vitamin D 500 IU; Vitamin E, 11 IU; Vitamin K, 1 mg; Choline, 30 mg; Niacin, 12 mg; D-pantothenic acid, 8 mg; Riboflavin, 2 mg; Vitamin B_{12}, .024 mg.
[c]Natuphos 600, BASF, Inc., Mt. Olive, NJ 07828
[d]Calculated composition.
[e]Analyzed composition, Ward Labs, Kearney 68848.

supplied .12% calcium and available phosphorus, .01% lysine and 12 kcal/lb metabolizable energy.

Pigs were vaccinated at arrival and revaccinated two weeks later for H parasuis, M hypopneumonia and Erysipelas. All pigs that died during the experiment were examined by a consulting veterinarian for cause of death. Pen sizes were not adjusted in the event of pig death or removal.

Individually identified pigs were slaughtered at SiouxPreme Packing Co. at Sioux Center, IA, on the week

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they weighed 240 pounds or more. Carcass lean was estimated by TOBEC (total body electrical conductivity) at the slaughter house. Daily lean gain was calculated based on the individual carcass lean estimate and the formulas of the National Pork Producers Council.

To further clarify the response of the pigs to the experimental diets, one front foot from two pigs from each pen of pigs (10 pigs/diet) in Trial 2 was collected at slaughter and frozen for later analysis. The feet were sent to Dr. Merlin Lindemann at the University of Kentucky for metacarpal bone breaking strength and ash content.

The pen of pigs was the experimental unit. The model included treatment, trial, weight block and all two- and three-way interactions. Means were separated based on preplanned contrasts. The contrasts chosen were:

1. UNL vs 85. This examined whether the 85 diet was deficient in lysine.
2. 85 vs PHY. This examined whether diets containing phytase and formulated according to the phytase suppliers recommendation gave equivalent performance to diets formulated without phytase.
3. PHY vs NEG. This examined whether diets containing phytase improved performance compared to diets without phytase but formulated for the phytase matrix.
4. PHY vs MIN. This examined whether diets containing phytase improved performance over diets that had the same level of total P and Ca, but were lower in energy and lysine by the amount credited to phytase by the supplier.

Table 3. Main effects of experimental treatments on pig performance.

	Treatment[a]						P-value			
	UNL	85	PHY	NEG	MIN		Contrasts			
Item	1	2	3	4	5	SE	1v2	2v3	3v4	3v5
Number pens	12	12	12	12	12					
Pig wt., lb										
Initial	56.1	55.6	56.3	55.7	56.3	.2				
First mkt (M)[b]	220.8	215.3	208.0	207.3	211.6	2.4	.0005	.043	NS	NS
Final (F)	247.0	241.8	244.1	239.8	237.9	2.1	.025	NS	NS	.0511
CV, %[c]	8.0	9.9	10.7	9.5	8.7	.8	NS	NS	NS	.0706
Daily gain, lb/d										
0 to M	1.72	1.60	1.56	1.60	1.60	.02	.0001	NS	NS	NS
0 to F	1.75	1.63	1.60	1.63	1.64	.02	.0001	NS	NS	NS
Daily feed, lb/d										
0 to M	4.87	4.77	4.74	4.72	4.83	.05	.049	NS	NS	NS
0 to F	5.13	5.08	5.23	5.14	5.26	.05	NS	.045	NS	NS
Feed/gain										
0 to M	2.84	2.98	3.04	2.95	3.04	.03	.0051	NS	.0418	NS
0 to F	2.94	3.13	3.27	3.16	3.22	.03	.0001	.0007	.0092	NS
Carcass % lean[d]	52.0	50.4	50.3	50.6	50.6	.3	.0021	NS	NS	NS
Daily lean gain, lb/d[d]	.67	.60	.59	.60	.60	.01	.0001	.137	NS	.137
No. dead/removed	4	10	6	2	7					

[a]UNL = University of Nebraska recommended; 85 = Lysine at 85% of UNL; PHY = Phytase to 85 diet with credits for lysine, energy, calcium, and phosphorus; NEG = PHY diet with phytase deleted; MIN = NEG diet with calcium and phosphorus added.
[b]Average pen weight when first pig removed for slaughter.
[c]Coefficient of variation of within pen weight when first pig removed for slaughter.
[d]Containing 5% fat.

Table 4. Metacarpal bone strength and ash (least squares means) - Trial 2.

	Treatment[a]					
Item	UNL	85	PHY	NEG	MIN	SE
Bone strength, kg/cm^2	199	208	204	195	197	7
Bone ash, %	58.3	57.8	56.7	57.7	57.8	.5

[a]UNL = University of Nebraska recommended; 85 = Lysine at 85% of UNL; PHY = Phytase to 85 diet with credits for lysine, energy, calcium, and phosphorus; NEG = PHY diet with phytase deleted; MIN = NEG diet with calcium and phosphorus added.

Results and Discussion

Tables 1 and 2 include the laboratory analysis of the pooled diet samples. As documented in the tables, the diets as sampled contained the formulated amounts of calcium, phosphorus, and lysine. While the diets were formulated to contain 500 FTU/kg phytase, they ranged from 445 to 533 FTU.

The main effects of the experimental diets on pig performance are given in Table 3. Decreasing the lysine to 85% of the UNL recommended level while maintaining energy, calcium and phosphorus at similar levels (85 vs UNL) resulted in a decrease in daily gain (1.63 vs 1.75 lb/d; P<.0001), a worsening in feed:gain (3.13 vs 2.94; P<.0001), carcasses with a lower lean percentage (50.4 vs 52.0%; P<.0021), and a decrease in the rate of daily lean gain (.60 vs .67; P<.0001).

There was no effect of experimental diet when comparing 85 vs PHY, PHY vs NEG, and PHY vs MIN for overall average daily gain. A trial × treatment effect was observed for daily gain and feed conversion, demonstrating the treatment variation among the three trials. However, in all trials, the performance of UNL pigs was the best.

Pigs fed the PHY treatment ate more feed than 85 pigs (5.23 vs 5.08 lb/d; P<.045) with no difference in feed intake for the PHY vs NEG or MIN treatments.

As a consequence of the difference in feed intake with no difference in daily gain, the PHY pigs had a worse feed conversion when compared to the 85 pigs (3.27 vs 3.13; P<.0007). Feed conversion for the PHY treatment was also worse than for NEG (3.27 vs 3.16; P<.0092), and not different from MIN.

There was no difference between

PHY and 85, NEG or MIN for carcass lean percentage or daily lean gain. There was no effect of experimental treatments on the number of pigs that died or were removed for poor performance during the experiment. Overall death loss and removal was 3.7%.

In this experiment, all treatments except UNL were designed to have lysine as a growth limiting nutrient. The claim for a .01% increase in lysine availability due to phytase addition was not supported as evidenced by the lack of improvement in performance for the MIN vs PHY treatments or the 85 vs PHY treatments.

Furthermore, the lysine limitation in the PHY treatment appears to have been severe enough to prevent any response of phytase in improving calcium and phosphorus availability. The lack of a response to the experimental diets on bone breaking strength and bone ash (Table 4), both considered sensitive indicators of phosphorus availability, supports this conclusion. The fact that MIN was not superior to NEG for any of the traits reported further supports the conclusion that the lysine limitation was severe enough to limit the possible phytase response.

Conclusion

These results document the impact of inadequate lysine on growth and carcass lean. They do not agree with the large body of evidence regarding the improvement in corn and soybean meal phosphorus availability with the addition of phytase to swine diets. They do suggest a limited, if any, response to phytase additions in diets in which lysine is limiting performance. The results were also unable to document the improvement in calcium, energy and lysine availability previously reported in poultry experiments from the addition of phytase to corn and soybean meal based diets.

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